



## Factors affecting bee communities in forest openings and adjacent mature forest



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### ABSTRACT

Anthropogenic disturbance of habitat is considered a contributing factor of pollinator declines, but some disturbances such as silviculture, may have positive implications for pollinator communities. Silviculture is a key source of disturbance in the eastern USA and thus, developing a better understanding of its ramifications for these keystone species is important for effective ecosystem conservation. We sampled bees in 30 forest openings created by group selection harvest as well as 30 sites in adjacent mature forest to examine the extent to which small forest openings support bees, to identify environmental variables influencing bee abundance and diversity, and to gauge their potential to augment bee populations in adjacent unmanaged forest. Bees were significantly more abundant and diverse in forest openings than in mature forest, but species composition did not differ. There was no relationship between opening size and abundance or diversity of bees in openings or adjacent mature forest. Both abundance and diversity were generally positively related to the amount of early-successional habitat on the landscape. Within openings, overall abundance and diversity decreased with vegetation height and increased with a metric representing floral richness and abundance. Notably, social, soft-wood-nesting, and small bees exhibited the opposite pattern in adjacent forest, increasing with vegetation height in openings and decreasing with greater floral richness and abundance within openings. Our results suggest that the creation of small forest openings helps to promote bees both in openings and adjacent mature forest, but this pattern is not consistent for all guilds.

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### 1. Introduction

Pollinators are vital to both ecosystems and humans worldwide, providing essential services for reproduction to the large majority of flowering plants (Kearns et al., 1998; Ollerton et al., 2011). Of all pollinating taxa, bees are the most effective at carrying out this critical ecological role (Winfrey, 2010). There are over 4000 species of native bees in North America (Cane and Tepedino, 2001), which contribute significantly to the pollination of both native plants and crops (Klein et al., 2003; Winfree et al., 2007a, 2008). A growing body of evidence indicates that bees and other pollinators are declining globally (Bartomeus et al., 2013; Biesmeijer et al., 2006; Burkle et al., 2013; Cameron et al., 2011; Koh et al., 2016). Anthropogenic disturbances that result in the loss, fragmentation, or degradation of pollinator habitats have been implicated as a major contributing factor to these declines (Aizen and Feinsinger,

2003; Goulson et al., 2008; Potts et al., 2010); however, not all disturbances are detrimental for bees since many species are associated with open, early-successional habitats that are created by disturbance (Grundel et al., 2010; Michener, 2007). Thus, developing a complete understanding of how anthropogenic disturbances influence bees is an important step toward effective pollinator conservation.

In a broad-scale meta-analysis, Winfree et al. (2009) presented evidence that human disturbances negatively impact bees on the whole, but when broken down by disturbance type, logging exerted a positive (albeit non-significant) influence on bee abundance. Indeed, recent studies have shown that certain silvicultural practices can promote bees (e.g., Hanula et al., 2015; Taki et al., 2010a). This suggests that silviculture, which is a common form of disturbance throughout the eastern USA and responsible for roughly 78% of all early-successional habitats in New England (King and Schlossberg, 2012), may contribute considerably to bee populations.

Even-aged silviculture appears to be effective at promoting overall bee communities (Hanula et al., 2015; Romey et al., 2007;

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Wilson et al., 2014), but has declined in favor of uneven-aged management throughout much of the U.S. (Oswalt and Smith, 2014). Stands managed with single-tree selection support more bees than unmanaged stands (Nol et al., 2006), but far fewer bees and lower diversity than even-aged regimes (Romey et al., 2007). Proctor et al. (2012) found that group selection, an uneven-aged method where groups of adjacent trees are removed from a mature forest matrix (Smith et al., 1997), supported significantly more bees than mature forest and suggested it was more effective at promoting bees than single-tree selection. These studies reinforce the notion that bees likely benefit from most forms of silviculture, but stop short of examining habitat characteristics (e.g., patch area), which can vary considerably among harvests and have been shown to be important for other taxa (e.g., Costello et al., 2000; Moorman and Guynn, 2001). Identifying the factors important for bee communities in various forest management scenarios will help conservationists and forest managers maximize the conservation value of their efforts.

Bees display considerable variation among species in several ways including dietary breadth (i.e., pollen specificity), sociality, body size, and nesting substrate. Accounting for these guilds can be of critical importance in understanding how bees respond to the environment as well as anthropogenic disturbances (Cane et al., 2006; Williams et al., 2010; Wray et al., 2014). Silviculture has the potential to impact guilds in different ways. For example, soil disturbance is common among silvicultural prescriptions, which may be beneficial for ground-nesting bees, but opening the canopy may also promote a floral community that is not conducive for floral specialists. Elucidating guild-specific responses to different silvicultural practices will be necessary in order to render a clear picture of how forest management shapes the pollinator community.

Landscape-level factors, in addition to microhabitat (Potts et al., 2003) and patch-level variables (Diaz-Forero et al., 2013), are important for bees (e.g., Winfree et al., 2007b). The presence of certain habitat types on the landscape such as grasslands have been shown to improve pollination in adjacent agricultural systems (Taki et al., 2010b). Because silviculture generally appears to promote bees (Hanula et al., 2016), it could have similar beneficial implications for pollination in adjacent unmanaged areas. This has not been thoroughly studied (although see Cartar, 2005 and Jackson et al., 2014), but could provide guidance to restoring pollination services to forested landscapes, the lack of which has been implicated in the decline of some mature forest plants (Willis et al., 2008) as well as other flora around the globe (Biesmeijer et al., 2006).

Heightened concern about native bee populations as well as increased emphasis on uneven-aged management suggests the importance of a more detailed understanding of the application of these methods for supporting these important pollinators. The objectives of this study were to (1) compare the bee community within forest openings to that of adjacent mature forest to illustrate the impact of group selection on bee communities, (2) identify microhabitat-, patch-, and landscape-level factors influencing bee abundance and diversity in both openings and adjacent forest, (3) quantify bee abundance and diversity at a range of distances from forest openings to gauge the potential for openings to augment bee populations in adjacent mature forest, and (4) examine the habitat associations of individual species.

## 2. Methods

### 2.1. Study area

We conducted this study in western Massachusetts, USA (42.46°N, –72.32°W; Fig. 1) in 2014 and 2015. The landscape

was over 90% forest, characterized as hardwoods-white pine and was primarily made up of red maple (*Acer rubrum*), red oak (*Quercus rubra*), black birch (*Betula lenta*), American beech (*Fagus grandifolia*), eastern hemlock (*Tsuga canadensis*), and white pine (*Pinus strobus*). Human development comprised <5% of the immediate landscape. Forest openings ranged in size from 0.08–1.29 ha and were created 4–8 years prior to sampling. The average nearest-neighbor edge-edge distance between forest openings was 43 m within harvest sites. Vegetation within openings consisted primarily of birches (*Betula* spp.), red maple, white pine, *Rubus* spp., mountain laurel (*Kalmia latifolia*), and various fern species. Residual woody debris from harvests was prevalent in all openings. The primary flowering plants during this study included *Acer rubrum* (early spring), blueberry (*Vaccinium* spp.; spring), *Aralia hispida* (summer), *Rubus* spp. (summer), and *Lysimachia quadrifolia* L. (summer). Few non-native plants were detected in openings.

### 2.2. Bee and microhabitat surveys

We randomly selected thirty openings for sampling across six harvest sites using bins based on opening size to ensure that a gradient of sizes were included. Sampling took place during three periods: spring (26 April–14 May), summer (1 July–17 July), and late summer (23 August–8 September). We collected bees once during each period using bowl traps, which consisted of 96 milliliter plastic cups (Solo®, Highland Park, IL) filled with water mixed with soap (blue Dawn® Liquid Dish Soap, original scent). To sample bees within openings, we established a transect of 5 sample points 5 m apart in each opening 15 m from the forest and parallel to the opening edge. To sample bees in forest, we established a second transect of 5 sample points 10 m apart starting 10 m from the opening and running perpendicular to the opening edge into the forest along east-west bearings to control for the effects of aspect (Matlack, 1994). We placed three bowls at each sampling point, one white, one fluorescent yellow, and one fluorescent blue, on the ground approximately 1 m apart. These colors have been shown to be most attractive to bees of eastern North America (Campbell and Hanula, 2007). We conducted sampling on sunny, calm days when the average temperature was >10 °C. We placed forest transects such that surrounding sources of shrubland habitat were never closer to points along the transect than the focal opening. After 24 h, bowls were collected and bees removed from bowl traps and stored in 70% ethyl alcohol. We cleaned, dried, pinned, labeled, and identified bees to species using online keys such as Discoverlife.org (Ascher and Pickering, 2016) and published references (e.g., Mitchell, 1960, 1962). We sent bees with uncertain identities to specialists Sam Droege, Michael Veit, and Dr. Jason Gibbs for confirmation.

We measured vegetation at 20 random locations within each opening. At each point, we placed a 3-m pole vertically and recorded the identity and height of the tallest plant species in contact with the pole or a vertical projection of the pole if vegetation was taller than 3 m. We used median vegetation height and coefficient of variation of vegetation height in the analyses to characterize vegetation structure. During each visit, we recorded the number of flowers by species within a 1-m radius of each sampling point. Absolute flower abundance yielded extremely heterogeneous data that over represented species that produce compound flowers made up of dozens of very small flowers (e.g., *A. hispida*). Flowering species richness was also not particularly descriptive of the floral community within openings because richness along transects only exceeded 3 species once for a single opening. To better describe the floral community within openings, we calculated the flowering species richness at each individual sampling point and summed those values for all 5 sample points in each transect. This new metric, which we refer to as “floral index,” allowed us to

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